Evaluation of a Dynamic Weather-Avoidance Rerouting Tool in Adjacent-Center Arrival Metering

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Presentation Sections

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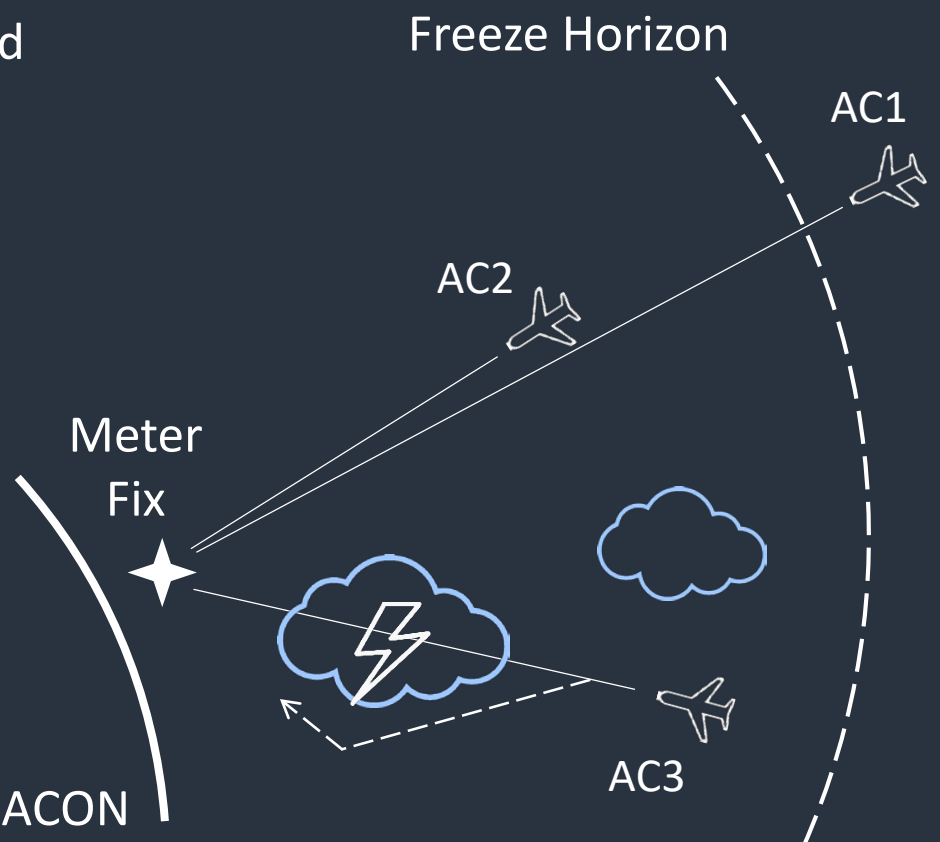
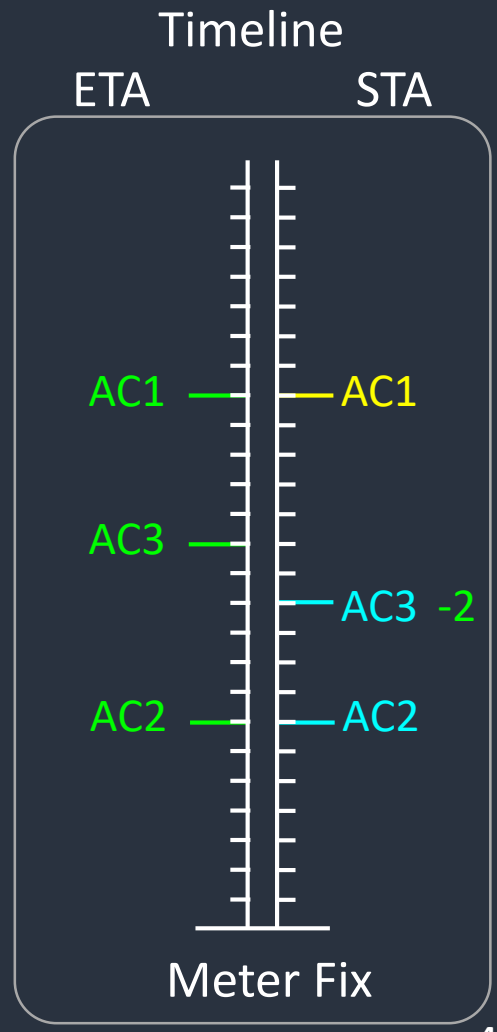
- Arrival Metering in Weather
- Dynamic Routing for Arrivals in Weather (DRAW)
- Relevant Past Work
- Objectives of the Study

Arrival Metering in Weather

- Estimated Time of Arrival (ETA) at Meter Fix is used to assign Scheduled Time of Arrival (STA).
- STA is frozen at Freeze Horizon (FH).
- Weather can disturb ETAs.
- When too many flights show bad STA, metering is switched to Miles in Trail (simpler, but reduced throughput).

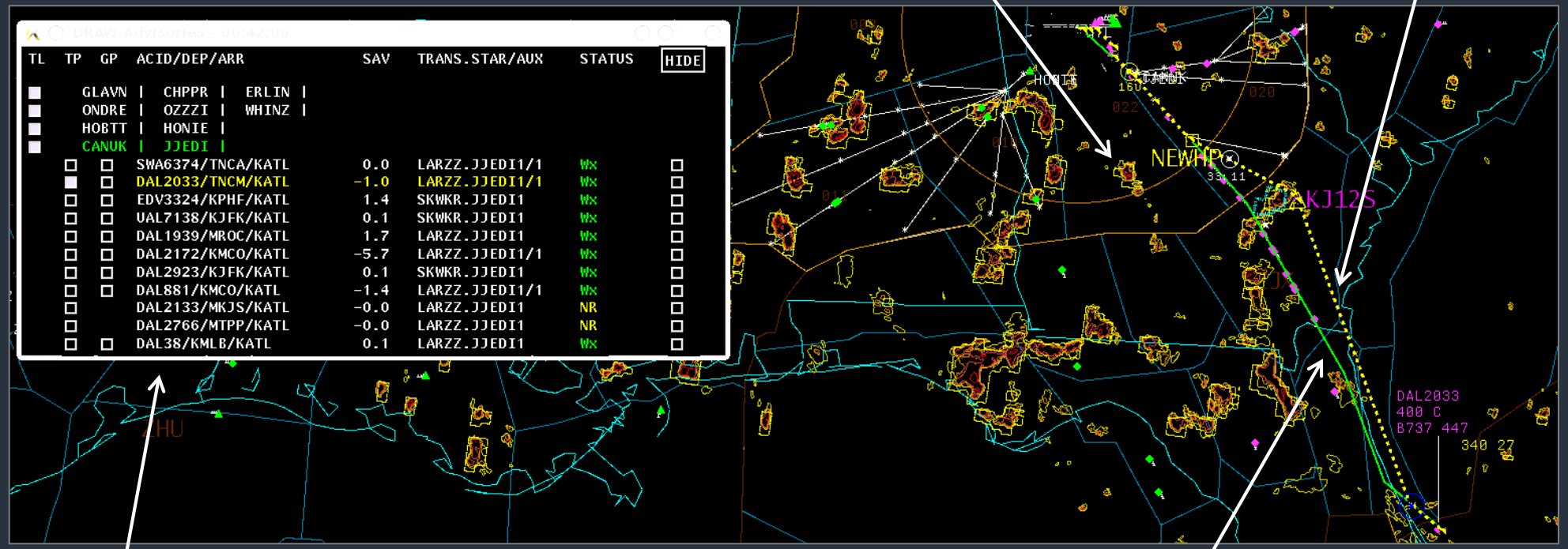




Dynamic Routes for Arrivals in Weather (DRAW)

- Is a decision-support tool for Traffic Management Coordinators (TMCs) at en-route facilities (“Centers”)
- Utilizes 4D current & forecast weather data:
  - Corridor Integrated Weather System (CIWS) for the current weather depiction
  - Convective Weather Avoidance Model (CWAM) forecast for weather-avoidance reroute computation
- Proposes Flight Plan route amendments that avoid weather:
  - Going around weather
  - Weather-free shortcut
  - Alternate Meter Fix (disabled in this study)
- [Goal] Allows arrival metering to continue under wider range of weather conditions

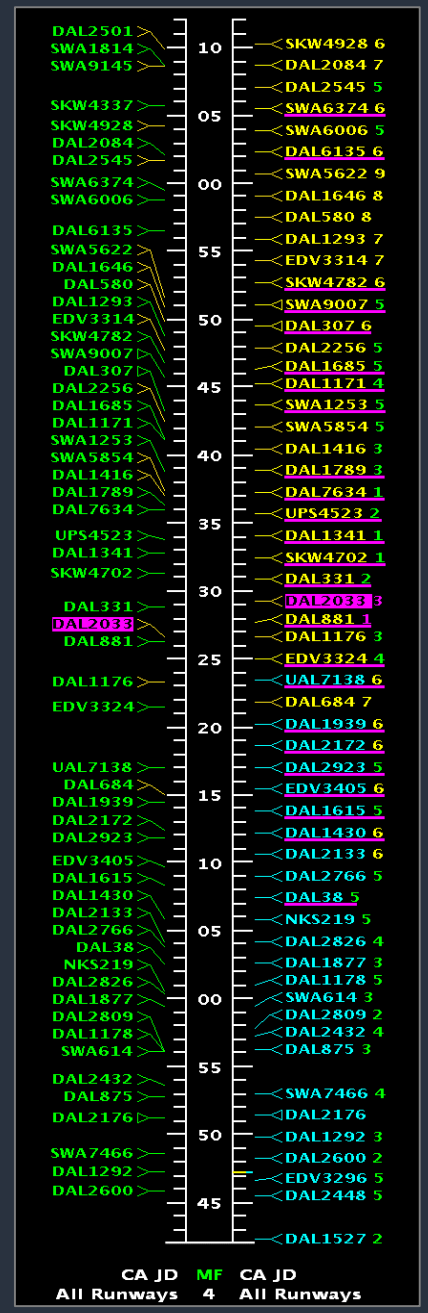
DRAW User Interface



DRAW Advisory List

Planview GUI (PGUI)

Flight Plan route



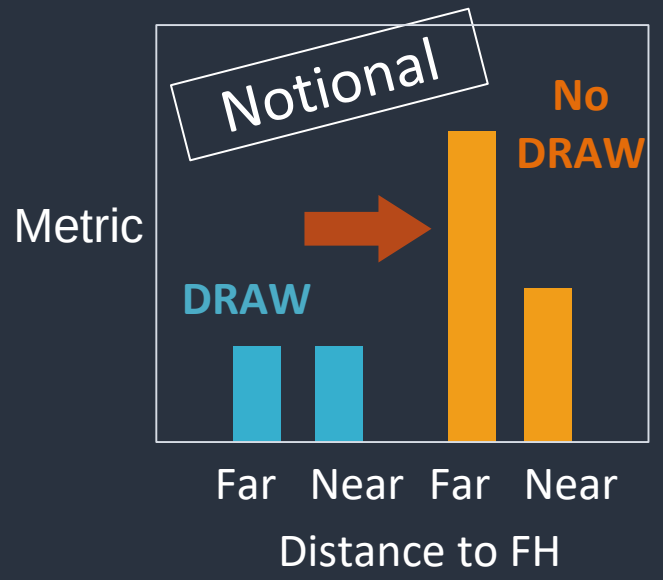
Timeline GUI (TGUI)

Relevant Past Work

- NASA's Dynamic Weather Routes (DWR) (McNally, et al., 2013/2015)
- Traffic Management Advisor (TMA) (Swenson, 1997)
- MITRE's Advanced Flight-Specific Trajectories (AFST) (DeArmon, et al., 2017)
- On acceptable thresholds for arrival metering delivery accuracy:
  - Human-in-the-loop simulation evaluations: error < 30-40 sec (Robinson, 2015)
  - Numerical simulations: error std dev < 60 sec in Atlanta Center (Shresta, 2009)
- Previous DRAW simulation evaluation (Isaacson, et al., 2018)
  - DRAW use resulted ~16 minutes earlier reroute advisories
  - No evidence was found that DRAW improved arrival metering performance

Objectives of the Study

- Investigate how arrival metering performance in weather was affected by:
  a) Use of DRAW
  b) Interaction of use of DRAW and the freeze horizon (FH) distance



- Observe inter-Center coordination for weather-avoidance and metering operations.

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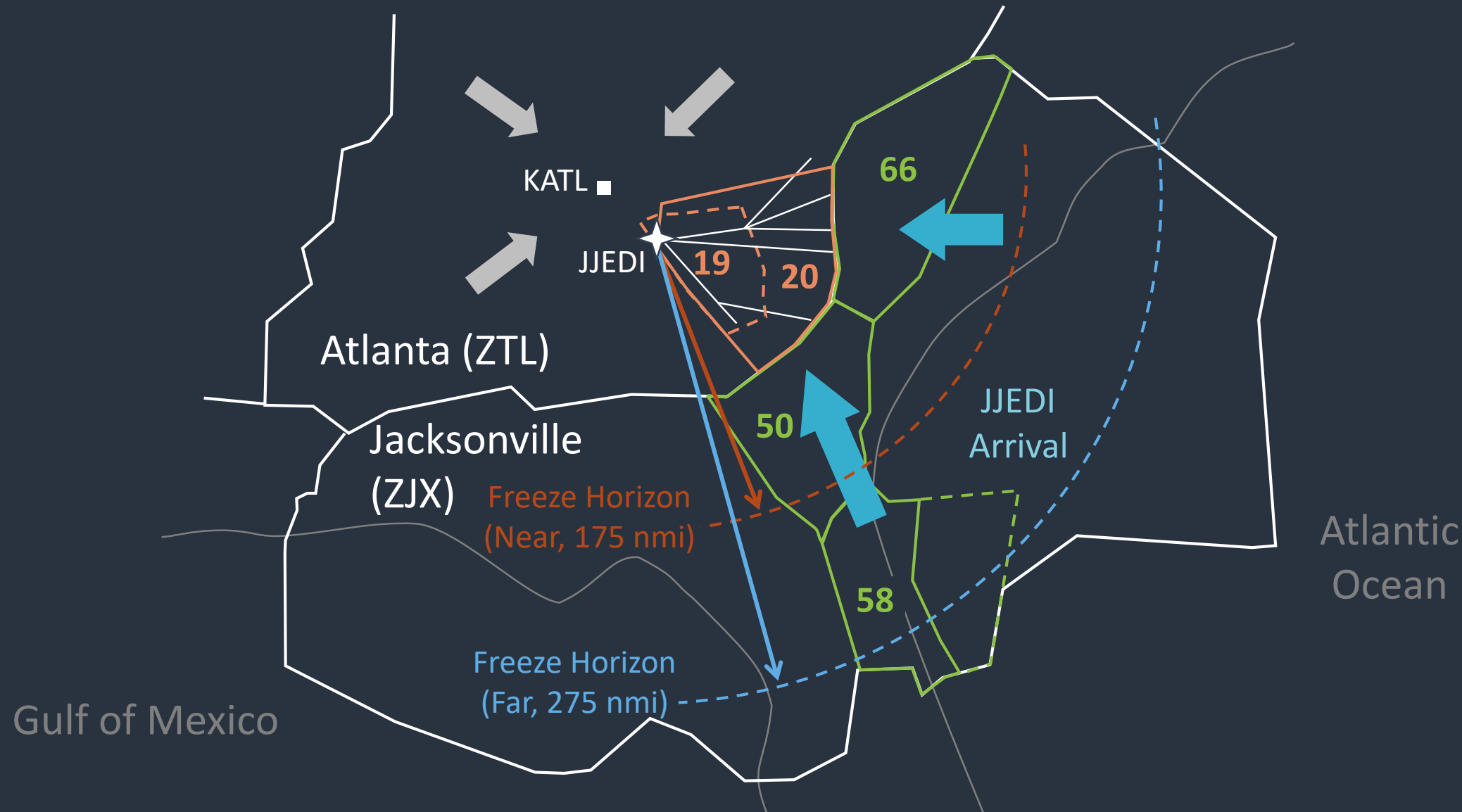
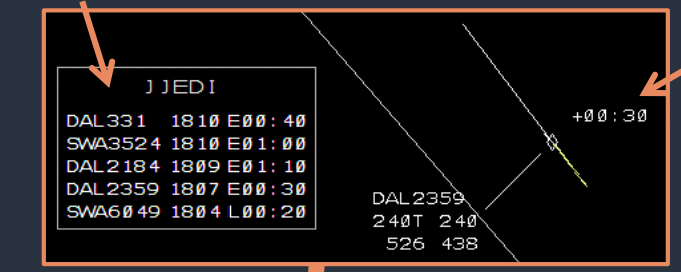
- Laboratory Setup
- Experiment Design
- DRAW vs. No-DRAW Condition
- Procedure

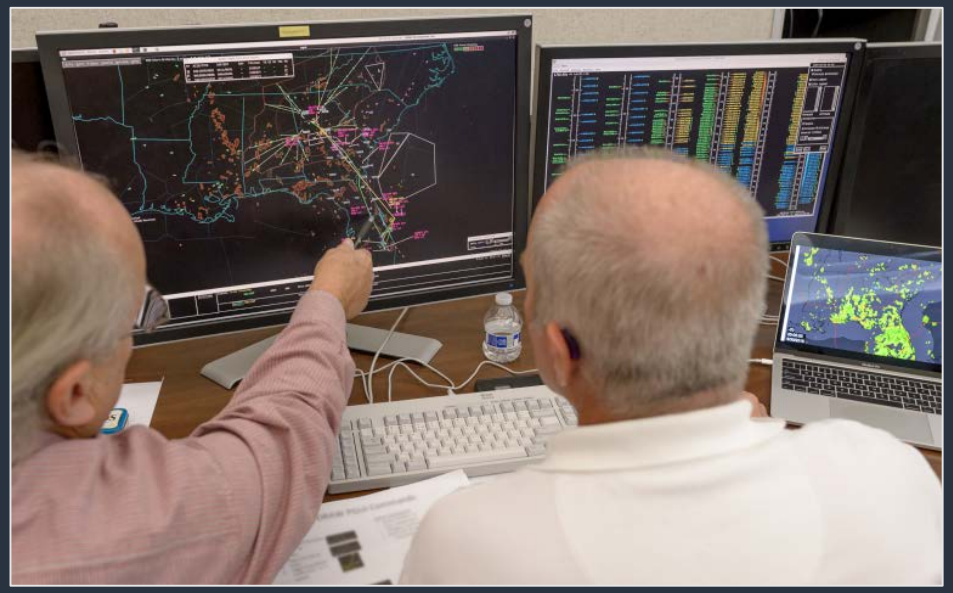
Simulated Airspace



Laboratory Setup



TMC (1)



Jacksonville (ZJX) TMC Atlanta (ZTL) TMC

Controller (6)

Pilot (6)

Reroute request

Radio

Experiment Design

- 2-week study, 10/22/2018 – 11/2/2018
- 16 runs for 2x2x2x2 test-matrix design:
  - DRAW Condition (DRAW vs. No-DRAW)
  - Freeze Horizon (FH) Location (Far vs. Near)
  - Weather Scenario (Weather 1 vs. Weather 2)
  - TMC & Controller Team (Week 1 vs. Week 2)
- 1 Baseline run (clear weather) in each week

DRAW vs. No-DRAW Condition

Functions Available in DRAW Condition

Function		DRAW	No-DRAW
DRAW Advisory		X	
Current CIWS weather on PGUI		X	X
Trial Planning:	Drag and drop to reroute	X	X
	Forecast CWAM conflicts	X	
	Metering impact on TGUI	X	

Procedure

- 2-hour runs, 9 runs per week (8 test-matrix runs + 1 Baseline)
- TMCs performed in 0-110 minutes, controllers & pilots in 15-120 minutes
- Manual adjustment of frozen STA was allowed at the TMC or controller's discretion, via any of the 3 methods:
  1. Controller swaps two flights' STAs
  2. TMC adjusts an STA along a TGUI timeline
  3. TMC reschedules the Meter List (ripples the list)

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- ATA Error w.r.t. STA at Meter Fix
- Manual Adjustments of STA
- Discussions

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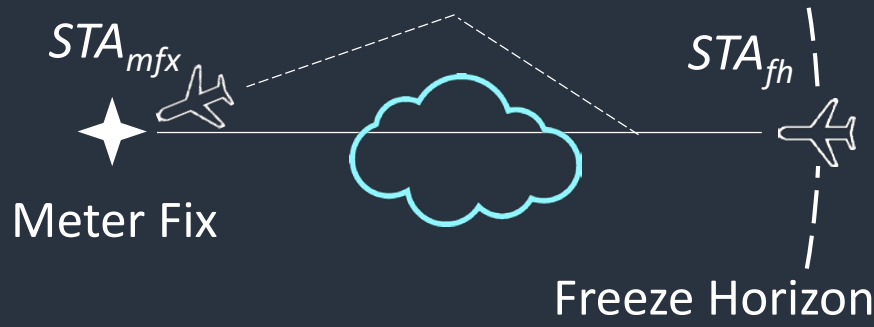
Actual Time of Arrival (ATA) Error

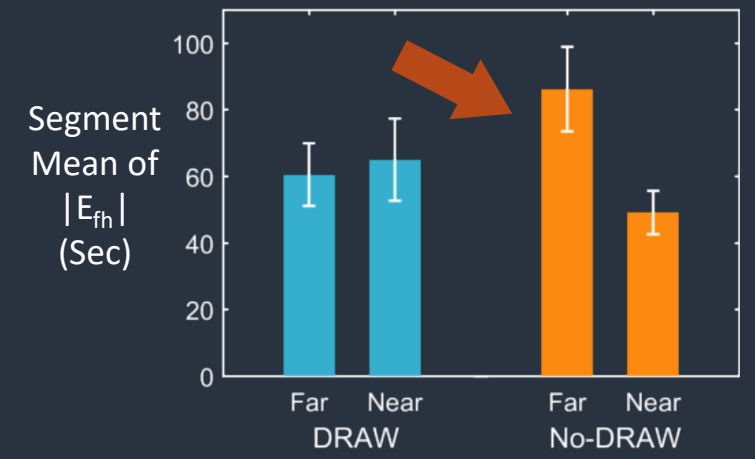
- 2 types of errors in the ATA at the Meter Fix:
  1) ATA Error with Respect to STA assigned at FH: $E_{fh} = STA_{fh} - ATA$
  2) ATA Error with Respect to STA indicated at Meter Fix: $E_{mfx} = STA_{mfx} - ATA$

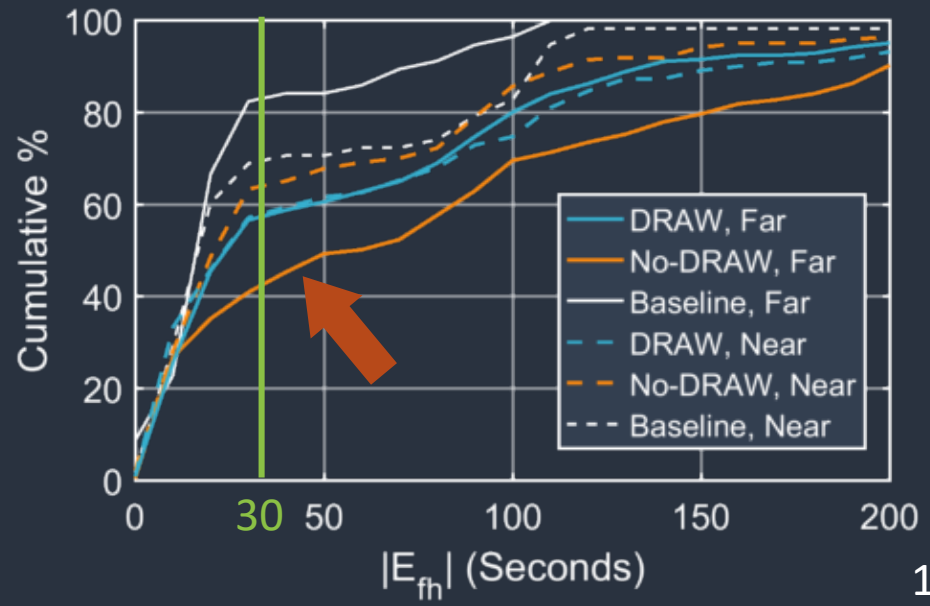


- Smaller E_{mfx} (#2) helps the TRACON work
- Smaller E_{fh} (#1) may suggest lower Center workload

1) ATA Error with Respect to STA at FH, $|E_{fh}|$

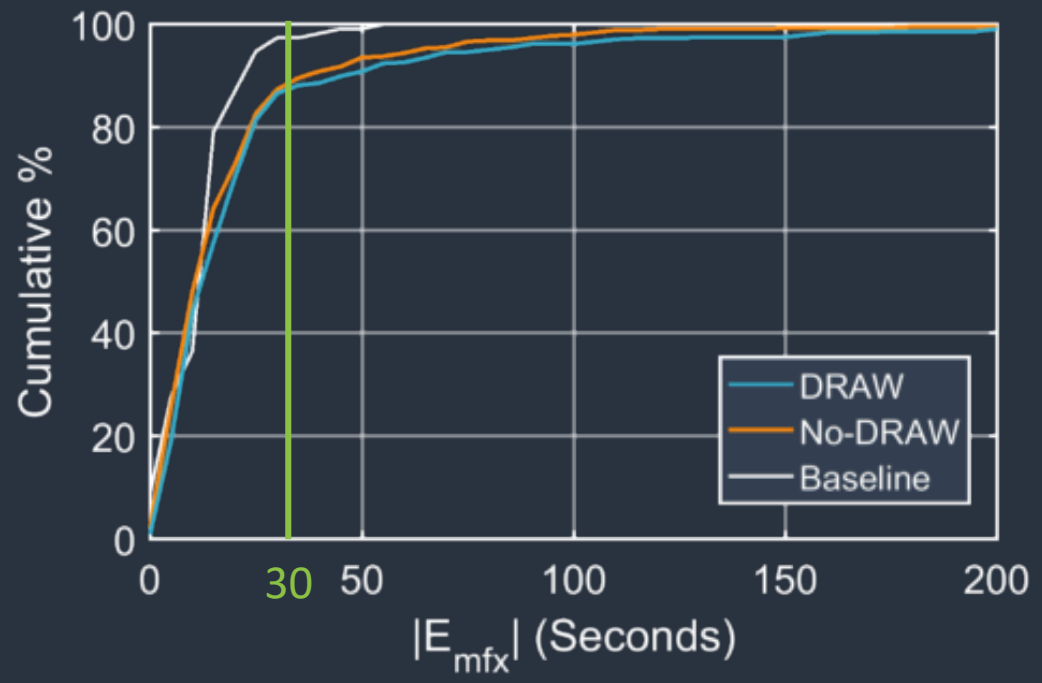
- The means of $|E_{fh}|$ over 30-minute segments (30-60, 60-90, and 90-120 min) were computed.
- Regression found the segment means were significantly larger in No-DRAW, Far FH (p = 0.023).
- Cumulative percentage of the ATA errors shows poor accuracy overall, but especially in No-DRAW, Far FH.
- The estimated std devs of the ATA errors were also large, 91 sec (DRAW) and 95 sec (No-DRAW).





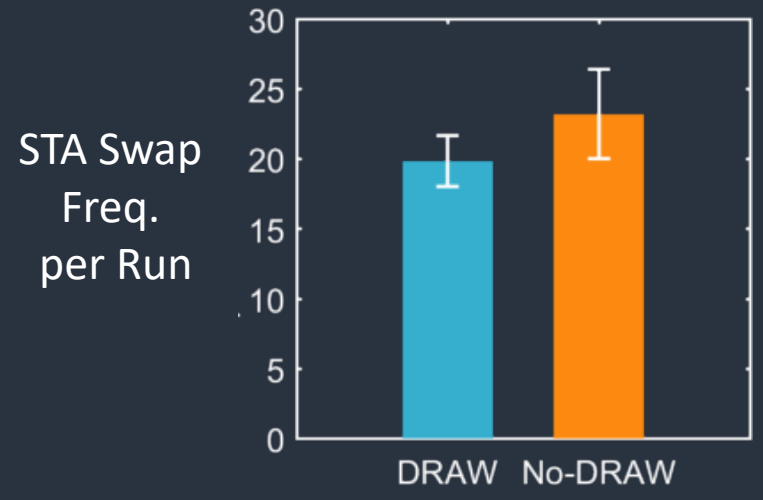
2) ATA Error with Respect to STA at MFx, $|E_{mfx}|$

- Regression did not find any significant effect.
- Cumulative percentage of the ATA errors showed both DRAW and No-DRAW runs achieved similarly good metering accuracy performance.
- The estimated std devs of the ATA errors were 29 sec (DRAW) and 42 sec (No-DRAW).

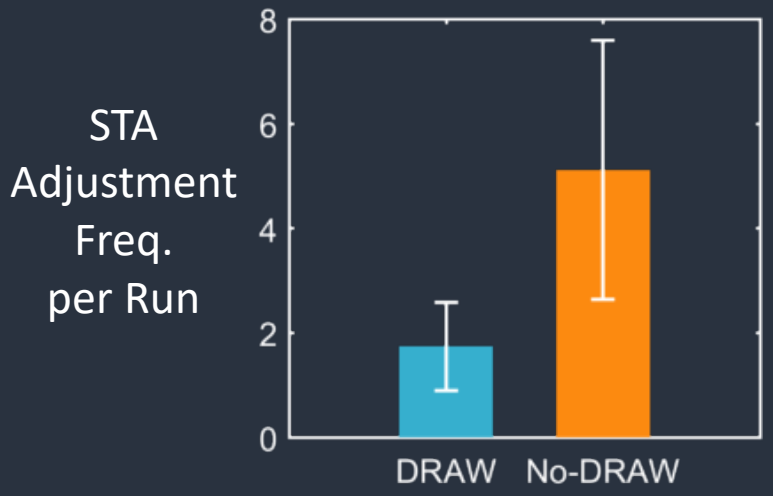


Manual Adjustments of STA

- Increased STA swaps by controllers in No-DRAW runs was found (p = 0.044).

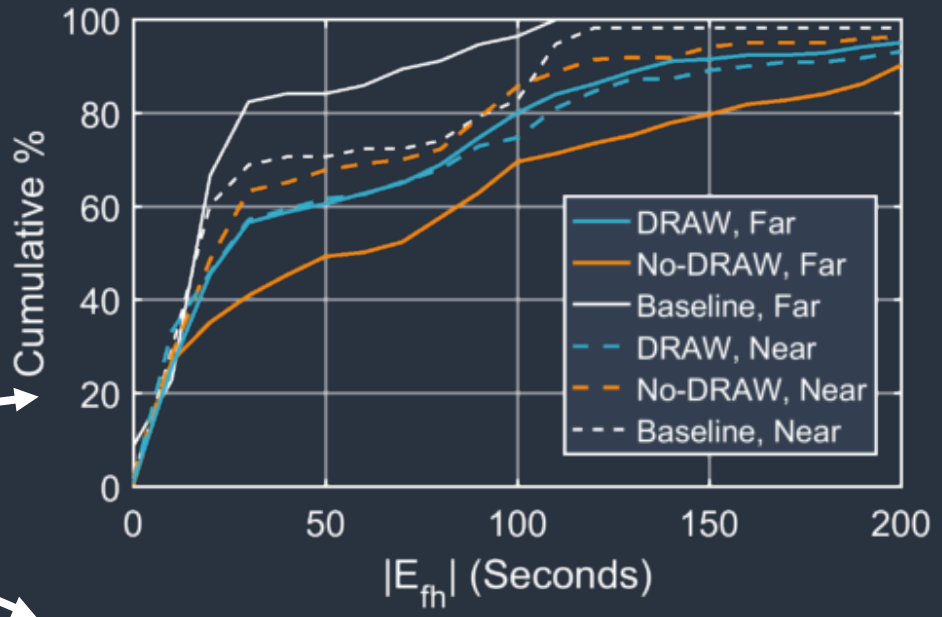


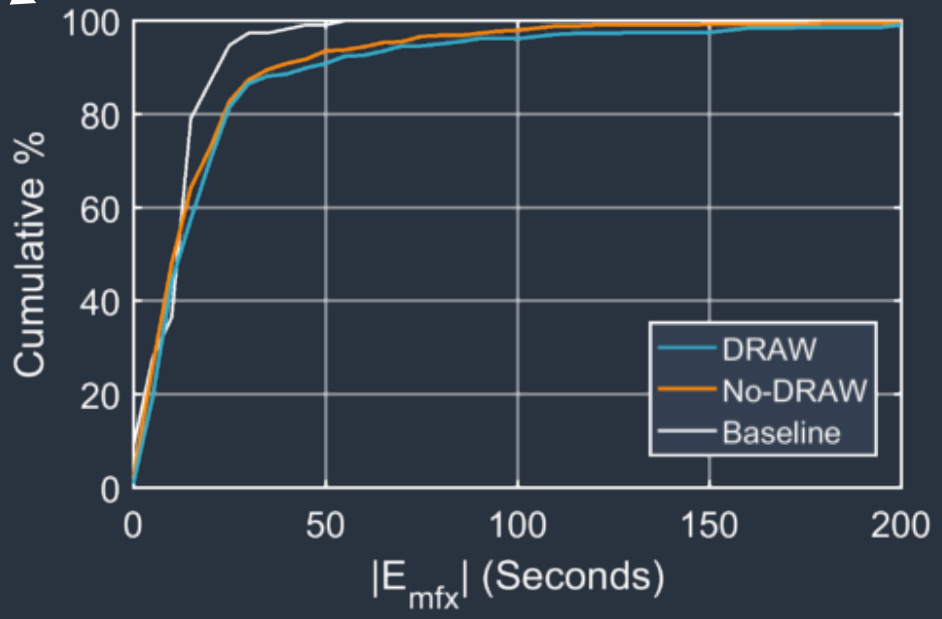
- Increased STA adjustments by TMC in No-DRAW runs was found (p = 0.069, marginal significance).



Discussions – ATA Error

- The 2 types of ATA errors showed very different pictures.
  1) ATA Error w.r.t. STA at FH (E_{fh}):
  2) ATA Error w.r.t. STA at Meter Fix (E_{mfx}):
- E_{fh} (#1) was reduced to E_{mfx} (#2) in No-DRAW runs by more manual STA adjustments.
- The STAs assigned at the FH are coordinated and optimized by the scheduler.
- Both ATA errors have to be small for successful metering.





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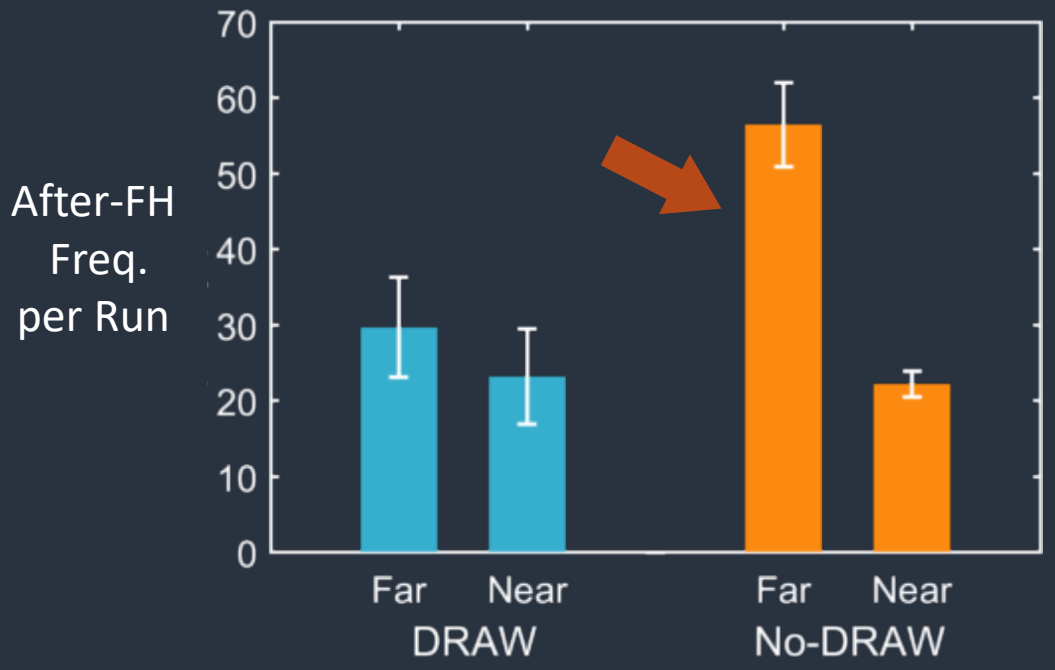
Route Amendment Locations

- The frequencies of the Flight Plan route amendments before and after the FH in each run were counted.

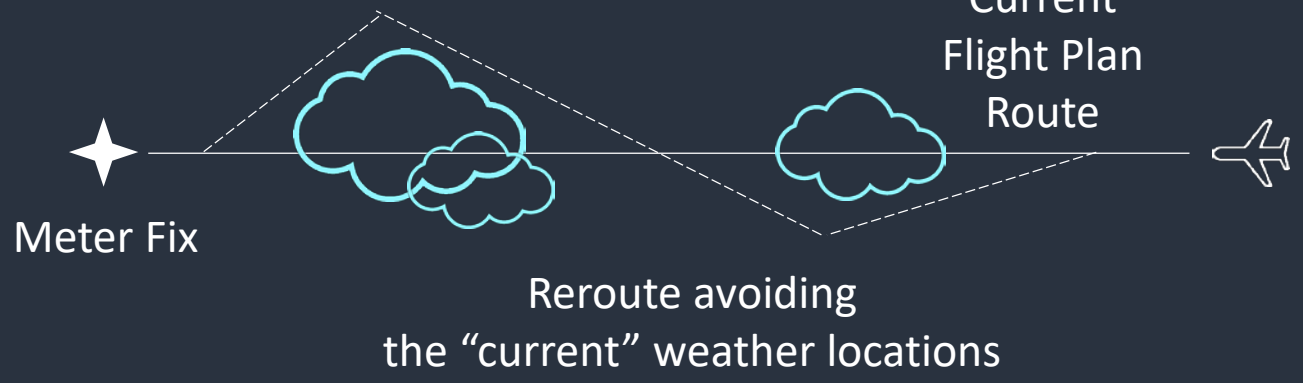


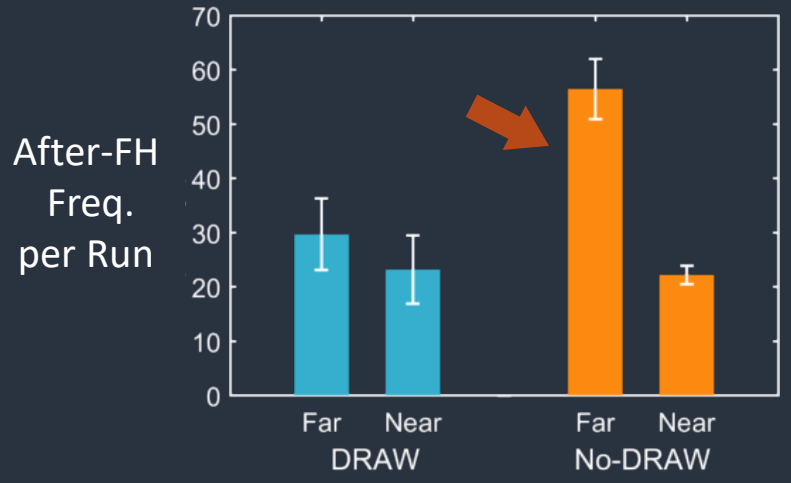
- The frequency of route amendments *after* the FH was significantly higher in No-DRAW, Far FH (p = 0.014).

Discussions – Weather Forecast Quality

- The quality of weather forecast is critical:
  - TMC liked having the anticipated weather locations on the PGUI map.

- Potential TMC mistake during high workload periods:





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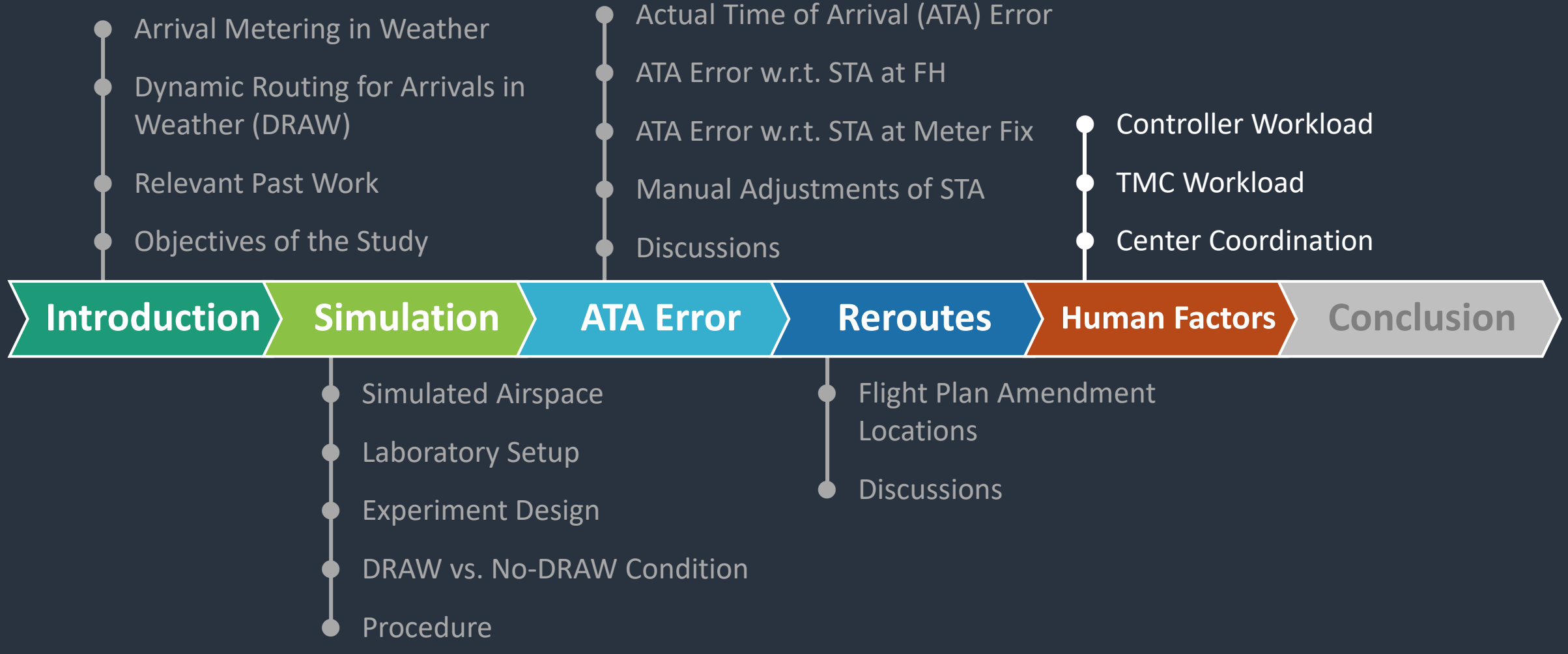
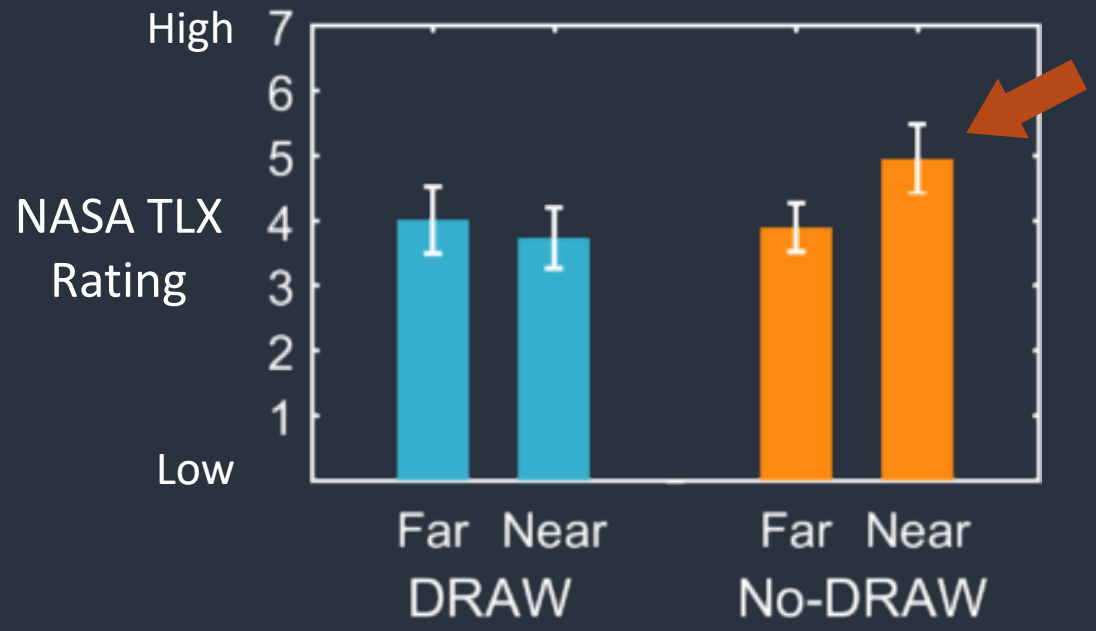


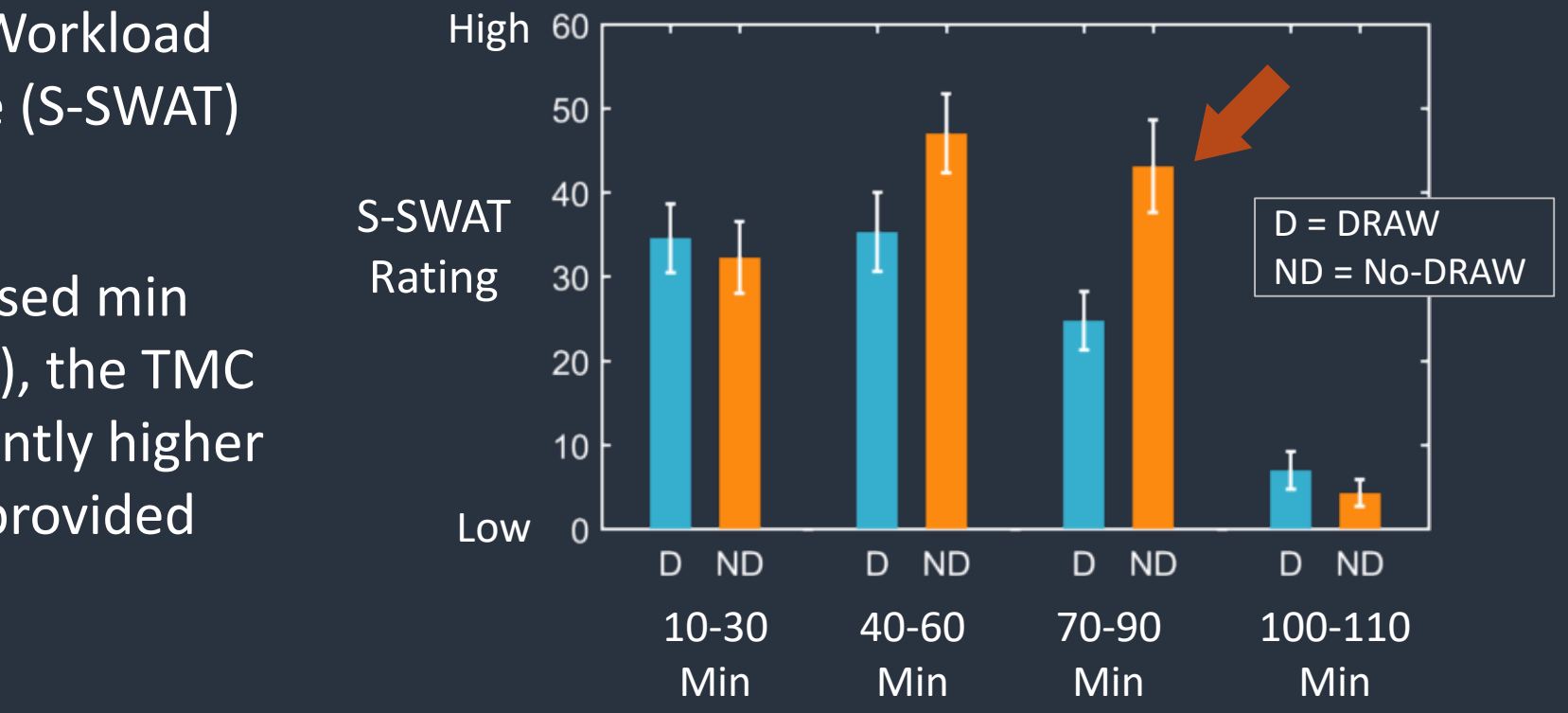
Controller Workload

- The sector controllers' post-run NASA TLX workload ratings (unweighted average of the subscale ratings) were higher in No-DRAW, Near FH (p = 0.005).



TMC Workload

- The Atlanta TMCs' real-time workload ratings were recorded every 10 minutes.
- Simplified Subjective Workload Assessment Technique (S-SWAT) scale was used.
- In 70-90 scenario-elapsed min segment (heavy traffic), the TMC workload was significantly higher when DRAW was not provided (p = 0.008).



Center Coordination

- In this study:
  - Atlanta (ZTL) TMC was the user of the DRAW.
  - Jacksonville (ZJX) TMC provided consultation.
- In field operation, however, ZJX should be the DRAW user.
  - Most weather-avoidance reroutes occurred in the ZJX airspace.
- Coordination when the responsibilities for weather avoidance and arrival metering fall into 2 different Centers?
  - A technological solution to enable the relevant Centers and the Command Center to view, discuss, and modify the reroute may be needed.

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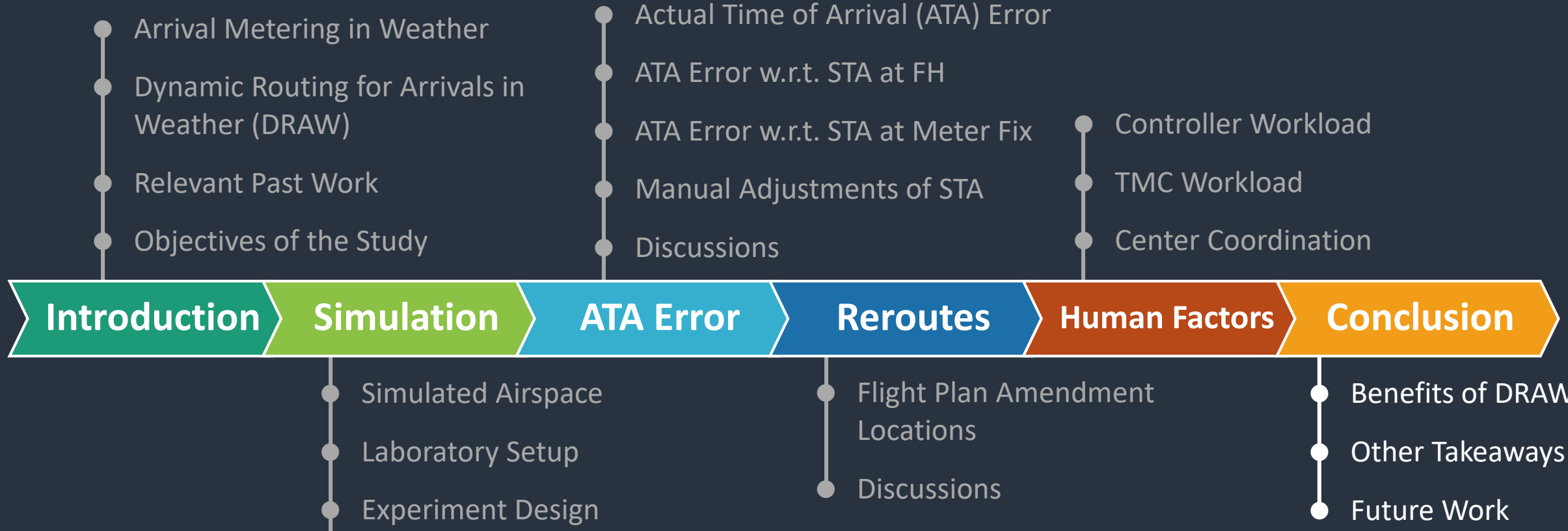

Benefits of DRAW Use

- Some DRAW benefits were observed regardless of the FH locations:
  - Reduced number of manual STA swaps
  - Reduced TMC workload (when the traffic volume was high)
- Some DRAW benefits were robustness to the FH locations:
  - ATA errors w.r.t. the STA at the FH ($|E_{fh}|$)
  - The number of reroutes after the FH
  - Controller workload
- The robustness benefits in advanced metering (e.g., Extended Metering).
  - E.g., fewer FHs further apart

Other Takeaways

- For successful arrival metering operation, ATA errors w.r.t. both the STA at FH and the STA at Meter Fix must be small.
- The DRAW benefits rely on good weather forecast.
- Clear strategy for inter-facility communication and coordination is needed.

Future Work

- Human-in-the-loop simulation demonstration of the DRAW software on the FAA's Time-Based Flow Management (TBFM) system (July, 2019)
- Technology Transfer to the FAA (September, 2019)

Thank You

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